# PLANNING SINGLE-SPAN SKYLINES

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# 1.0 INTRODUCTION

In recent years, there has been a growing demand for a yarding system that can economically transport logs from steep terrain without a dense access road network. Such a system must also be able to transport logs without disturbing sensitive soils or damaging watersheds. And in many areas, the public demands that the logged area be esthetically pleasing to the eye.

The single-span, skyline-crane yarding system is capable of yarding logs from steep terrain and meeting the above requirements if cutting units are properly designed. Numerous skyline-crane shows have been tried in the Pacific Northwest with varying degrees of success. One contributing factor to suboptimal performance has been insufficient planning of the skyline layout. To date there has been little information available to foresters, engineers, and loggers on the layout of skyline-crane operations.

It is, therefore, the purpose of this paper to provide those who have the responsibility for logging planning with the criteria for selecting areas suited to skyline-crane yarding.[1]

# 2.0 LOGGING PLANNING

All operations, from felling trees to unloading logs at a delivery point, must be considered when a logging plan is developed. A comprehensive plan for an entire forest area on a compartment basis should be completed before onsite location of cutting units begins. This comprehensive plan is the "blueprint" which designates each area to be harvested by the yarding equipment best suited to its terrain and to modern forestry practice. Vehicle road location must also be carefully considered in comprehensive planning so that its location is compatible with logging systems as well as other forest values.

J. Kenneth Pearce[2] has listed several factors to be considered:

> The logging planner is the 'architect' of the logging plan. To arrive at the best plan, he must consider many factors. Given the basic data on timber and topography, logging planning requires the concurrent consideration of the following factors:
>
> 1. The physical requirements of the applicable logging methods.
> 2. The most economical combination of yarding costs, road construction costs and trucking costs.
> 3. The silvicultural system and the priority sequence of cutting.
> 4. Protection of the uncut stand and soil and water resources.
> 5. The safety of the men working on the landings and traveling the roads.

Some of these factors may conflict. The final logging plan may be a compromise reached after weighing all factors. The relative weight to be given each factor is an administrative decision based on policy.

## 2.1 CRITERIA FOR SELECTING AREAS FOR SINGLE-SPAN SKYLINES

The most important objective of single-span skyline planning is to obtain adequate deflection so that the skyline has the required load-carrying capability. Deflection is defined as the vertical distance between the chord and the skyline as measured at midspan.[3]

1 A skyline-crane operation is designed to yard logs laterally to a carriage as well as to transport them either up or down a skyline to a landing. The skyline-crane should not be confused with Northbend, Southbend, or Tyler skyline yarding systems. These do not have the same lateral skidding capabilities as skyline-cranes because their butt rigging is pulled laterally by the haulback line, with a side block located adjacent to the skyline. These systems do, however, operate on single-span skylines.

2 Pearce, J. Kenneth. Forest engineering handbook. Bur. Land Manage., U.S. Dep. Interior, Oreg. State Office. 1961

3 Lysons, Hilton H., and Mann, Charles N. Skyline tension and deflection handbook. Pacific Northwest Forest & Range Exp. Sta. U.S.D.A. Forest Serv. Res. Pap. PNW-39, 41 pp., illus. 1967.

Topography is the principal contributing factor to obtaining adequate deflection.

In addition to topography, other considerations for selecting areas are: the transportation plan, log landings, skyline anchors, spar trees, and overall costs of operation.

### 2.1.1 SUITABLE TERRAIN

Three types of forested terrain confront the skyline planner: concave, uniform, and convex slopes. Single-span skylines are best suited to concave topography since this condition presents the least problem in obtaining adequate deflection. A concave slope with a single-span skyline is illustrated in figure 1C.

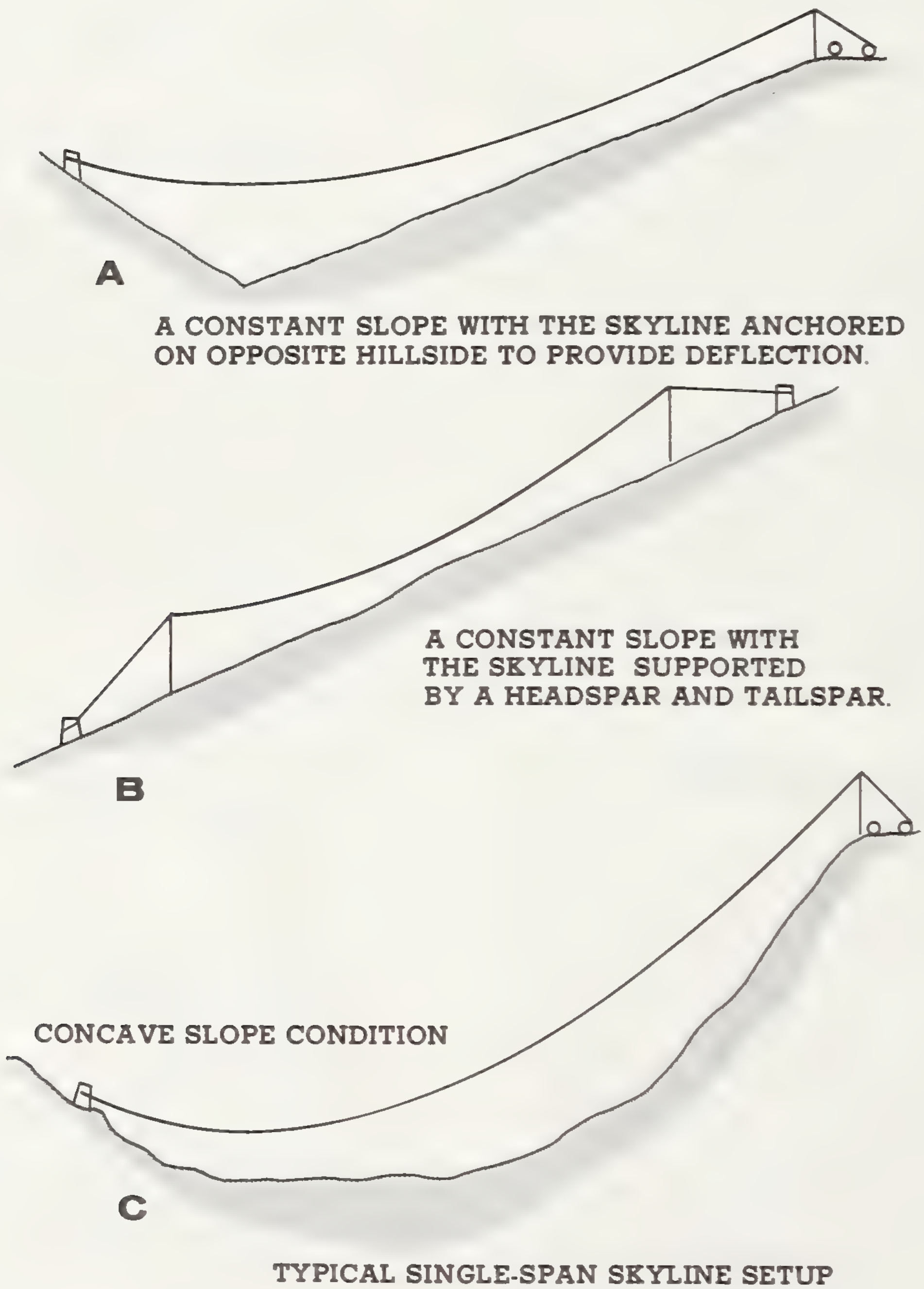


*Figure 1.*—Typical single-span skyline setup.

Successful single-span skyline operations can also be made with constant slope conditions, although horizontal distance obtainable is usually less than with concave slope. Figure 1B shows a constant slope with the skyline supported by spar trees. Where the lower portion of a constant slope area to be yarded is adjacent to a valley or a drainage, it is frequently possible to anchor the skyline on the opposite hillside (fig. 1A), eliminating the need for a spar tree and resulting in savings of rig-up time and cost.

The convex slope condition presents the planner with the greatest difficulty, since normally it cannot be logged with a single-span skyline. The only exceptions to this are when the convex portion is part of a longer, generally concave, slope or when the convexity is so slight that spar trees can be used to overcome the problem. In cases other than these exceptions, a multi-span skyline is necessary, which introduces other problems beyond the scope of this publication.

Either of the three choices—concave, uniform, or convex terrain—directly influences the skyline length and height. The effect of this is discussed in section 2.1.6.

### 2.1.2 COMPATIBILITY WITH TRANSPORTATION PLAN

The overall transportation plan, including roads both built and planned, has the largest single influence on deciding whether to yard the logs uphill or downhill. In addition to the usual considerations in road planning such as construction costs, grades, soil stability, and multiple use requirements, the following log-carrying methods should be considered:

| *Yarding direction* | *Log-carrying method* | *Soil disturbance* |
|---|---|---|
| Uphill | Free | None |
| Uphill | Drag | Slight |
| Downhill | Free | None |
| Downhill | Drag | Varies[1] |

1 Soil damage varies from slight to severe, depending upon degree of slope. For moderate downhill slopes where the log drags, the disturbance is slight. However, as the slope increases, a point is reached where the log overruns the inhaul line, allowing it to swing out of control. This usually causes severe soil disturbance, damage to any residual trees, log breakage, and possible damage to the skyline carriage.

### 2.1.3 ADEQUATE LANDINGS

Landings for successful skyline-crane operation must include an area large enough to land logs safely and provide both storage and loading room for the logs. As a rule, the landing size for skyline-cranes is comparable to that required for high-lead logging.

Where landing space is inadequate, it may be necessary to use a rubber-tired or crawler tractor to swing the yarded logs to nearby areas for storage and loading. This added handling cost may necessitate reconsidering the location of the landing on the cutting unit.

The area where the logs are to be unhooked from the chokers should be reasonably level. This reduces the tendency of logs to roll or slide downslope.

### 2.1.4 ADEQUATE ANCHORS

Anchors are a basic requirement for setting up and operating skylines. They must be able to withstand the severe pull of the skyline. At present, only experience can indicate the capability of an anchor stump for a given ground condition. As a guideline, however, the following should be considered when stumps are examined for skyline anchors:

1. *Stump diameter.* — Since larger stumps are preferable, it is important to be aware of the possible lack of larger stumps at the upper end of a skyline.
2. *Stump condition.* — Stumps should be reasonably free of rot and have a sound root structure.
3. *Soil type and depth.* — Shallow soils may indicate the lack of a deep root structure.

Where these things become problems, it is often possible to obtain a satisfactory anchor by securing the skyline to several stumps. If no suitable stumps are available, a deadman, or buried logs, may be used for anchor. Sites for deadman anchors should be judged on the practicability of getting excavation equipment to the site and the depth of soil to solid rock.

### 2.1.5 ADEQUATE SPAR TREES

Spar trees may be required to support the skyline at one or both ends. Where spar trees are needed to provide clearance for the skyline, standing trees selected for spars should meet applicable safety code requirements.

When a headspar is required at the landing, a mobile steel spar is often used. Tailspars are usually rigged trees. Spar trees, whether they are rigged or mobile, must be located in alignment with anchor points and the landing area.

### 2.1.6 LENGTH AND HEIGHT OF SKYLINE

The type of terrain within the cutting unit boundaries is the major factor in determining the length of the skyline. The planner should be aware, however, that equipment limitations, access road costs, frequency of setup, yarding cycle time, and yield per acre all affect optimum skyline length. Single-span skylines have been employed in the Pacific Northwest at yarding distances up to 4,000 feet. The maximum skyline length is usually limited by either the available yarding equipment or the allowable deflection as provided by the terrain.

These same limiting factors of equipment and terrain also affect the allowable height of the skyline, which is measured from the ground to the skyline when it is loaded with only the carriage. The restricting factor in this case is the skidding line capacity of the skyline-crane carriage. Present maximums range from 100 to 400 feet of cable.

The effect of the height of the skyline above ground varies, depending on whether a "live" skyline or a "standing" skyline is used. With a live skyline, which can be raised or lowered by the yarder operator, the problem of limited skidding line capacity can be readily overcome. However, the standing skyline, which is fixed at both ends, does not have this flexibility. Thus, careful analysis by the planner is necessary to avoid exceeding the skidding line capacity.

The skidding line must be long enough to reach the ground, plus an allowance for lateral skidding.

Exact determination of skyline height can only be resolved through procedures covered below. Where this height is too great, it is necessary to change either the skyline road location or the anchor point location.

### 2.1.7 ECONOMICAL OPERATION

In an evaluation of the economic feasibility of a skyline-crane operation, total logging costs should be considered. Skylines are capable of transporting logs for long distances, thus reducing access road mileage and costs.

The following should be carefully considered in an evaluation of the economic feasibility of a cutting unit:

1. Conversion (the amount available for logging after minimum acceptable stumpage is subtracted from the delivered price of logs).
2. Total volume to be yarded from a cutting unit.
3. Area previously yarded within cutting unit.
4. Number of operating days per year.
5. Size of logs.
6. Skyline distance.

The cost savings of less access road construction, hauling, and road maintenance must be considered along with yarding costs when logging cost estimates are made. Skyline-crane cost analysis should include the summation of all logging costs from the stump (including felling) to delivery point.

Direct yarding costs, which include log production plus setup and takedown, may vary widely on skyline roads within a cutting unit. The decision to accept or reject a proposed cutting unit should be based on an average cost for all skyline roads within a cutting unit, rather than on the one that

appears most profitable or that has the highest cost.

Skyline yarding costs should not be compared directly with yarding costs of other systems since yarding distances for skylines may be greater. Instead, total logging costs (i.e., all costs from stump to delivery point) should be used in a comparison.

## 2.2 LAYOUT OF CUTTING UNITS

Once the comprehensive logging plan has been completed, layout of cutting units may be started. This phase of work is done by use of aerial photographs, topographic maps, and timber-type maps. Aerial photos in stereopairs may be used to identify preliminary landings, anchor points, and spar trees. Anchors may be located within proposed cutting units, but more often it is desirable to locate them outside a cutting unit to improve deflection or to take advantage of larger anchor stumps.

Detail identified on the photos may be transferred to a topographic map for use in laying out cutting units and skyline roads. Good-quality skyline road profiles may be plotted from topographic maps having a scale of 1 inch = 400 feet and a contour interval of 20 feet. The planner should be aware that accuracy of topographic maps in mountainous terrain may be questionable and suitable only for preliminary work pending onsite confirmation.

Accurate data on timber volume per acre and log size are needed for estimating yarding and rigging costs. Timber-type maps should also be superimposed on the topographic maps to identify more clearly where skyline roads may be located.

Figure 2 illustrates location of skyline roads in a forest area which has been laid out for single spans.

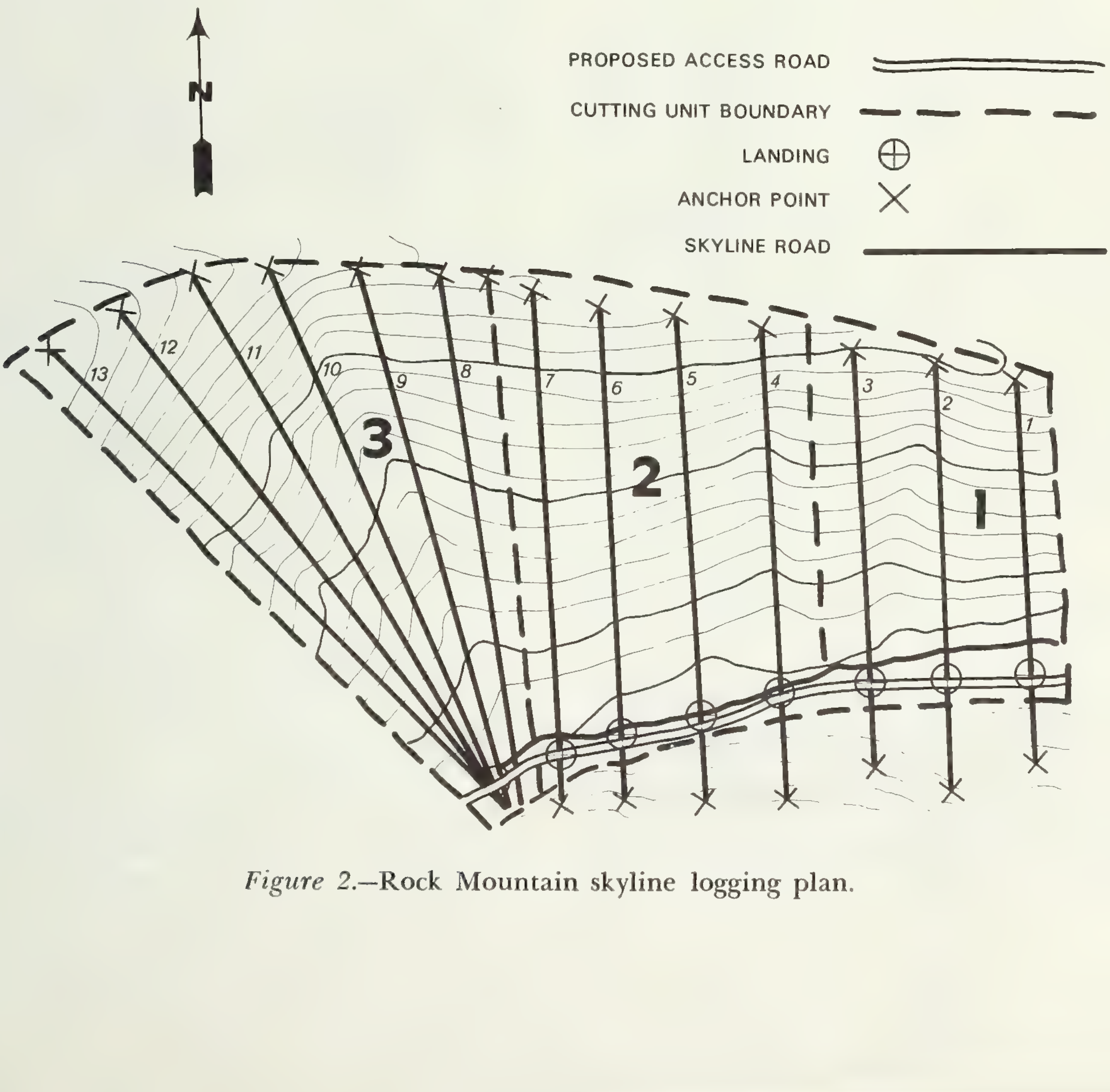


*Figure 2.*—Rock Mountain skyline logging plan.

## 2.2.1 SELECTION OF RECTANGULAR LAYOUT

Rectangular cutting units are generally laid out on hillsides where contours are reasonably straight (see fig. 2, units 1 and 2). Skyline roads in such layouts are parallel, or nearly so, depending on availability of anchors and spar trees.

This layout results in little or no lateral ground slope, thereby minimizing problems in lateral yarding of the logs.[4] Lateral ground slope occurs when the skyline crosses the contour at an angle other than 90°.

## 2.2.2 SELECTION OF FAN-SHAPED LAYOUT

Fan-shaped cutting units are generally laid out in areas where contour lines curve around ridge points or into drainage heads. Skyline roads in such a layout radiate from one anchor point, usually located at the landing. Cutting unit 3 in figure 2 illustrates a fan-shaped cutting unit.

## 2.3 LOCATE SKYLINE ROADS

Parallel skyline roads may be spaced about 300 feet apart. Spacings greater than 300 feet cause a sharp increase in cycle time. [5] Other influences on spacing are areas broken up with small creeks and ridges. Locating a skyline road down a creek should be avoided because the skidding line must then be pulled upslope on both sides of the skyline and the logs will be skidded downslope; logs will roll and cause hangups.

In partial cuts such as thinnings, road spacing is usually closer than in clearcuts. Tests in a Douglas-fir thinning operation showed that logs could be yarded from a 220-foot parallel skyline road spacing with little damage to remaining trees.[6] Road spacing distance on fan-shaped layouts is measured at the tailspar or anchor point.

4 Binkley, Virgil W. Economics and design of a radio-controlled yarding system. Pacific Northwest Forest & Range Exp. Sta. U.S.D.A. Forest Serv. Res. Pap. PNW-25, 30 pp., illus. 1965.

5 Report on administrative study of skyline logging. U.S.D.A. Forest Serv., Region 5, Klamath National Forest, Yreka, Calif., 23 pp., illus. 1966. (Also, see footnote 4.)

6 Binkley, Virgil W., and Williamson, Richard E. Thinning Douglas-fir on steep slopes. Forest Ind. 95(2): 60-61, illus. 1968.

## 2.3.1 PLOT PRELIMINARY SKYLINE ROAD PROFILES

When preliminary skyline roads have been located on a topographic map, profiles of these roads may be plotted with a scale of 1 inch = 100 feet for both horizontal and vertical distance.

## 2.3.2 DETERMINE SKYLINE LOAD-CARRYING CAPABILITY

Allowable deflection may be determined by the "chain and board" method outlined in Lysons and Mann (see footnote 3), and skyline tension and load-carrying capability may then be calculated for each profile by the use of appropriate tables and worksheets provided therein. If deflection is not adequate for transporting a minimum load, the skyline road must be relocated, which may require changing cutting unit boundaries and landing locations.

When there is little or no change in topography, it is not essential to profile each skyline road. When topography changes, make checks by plotting new profiles.

## 2.3.3 DETERMINE MAXIMUM ALLOWABLE SKYLINE HEIGHT ABOVE GROUND

The maximum above-ground height of a standing skyline is dependent on the skidding line capacity of the carriage. In determination of maximum height, an allowance for lateral skidding distance must also be considered. If maximum skyline height occurs at the landing, an allowance for lateral skidding may not be required. This sometimes occurs when logs are transported over ground previously yarded by another system, either as part of the current operation or prior to it.

If the height of the skyline is greater than the skidding line capacity of the carriage to be used, anchor points may have to be moved or a live skyline used instead of a standing skyline.

Skyline height above ground may be found by taking appropriate measurements from the skyline profile used in the chain and board method (see footnote 3).

## 2.4 PRELIMINARY LOGGING COST ANALYSIS

Before the start of onsite layout of cutting units, it is wise to make a logging cost analysis. Even though payload-carrying capability of each skyline may appear to be adequate, logging costs may be unacceptable. If cost estimates are favorable, fieldwork may be started which will provide accurate ground profiles for each skyline road.

The procedures for estimating yarding costs for skyline-crane yarding systems are complicated and beyond the scope of this document.

# 3.0 ONSITE LOCATION AND DESIGN OF CUTTING UNITS

When preliminary logging cost analysis shows that a particular area may be logged economically, onsite location may be started. This fieldwork and the resulting skyline road profiles are used to verify the layout made on the topographic map. The following sections, 3.1 through 3.3.4, define the major steps which should be followed in the onsite work and the final planning.

## 3.1 RECONNAISSANCE

Before fieldwork such as boundary and profile traverse are started, an "on-the-ground" reconnaissance is needed to verify location of the landings, anchors, and spar trees identified on the aerial photographs. This work is done with aerial photographs and topographic maps as aids. The following steps briefly outline a reconnaisance of a proposed skyline cutting unit.

### 3.1.1 SELECT AND MARK ANCHORS

Standing trees, selected for anchors, must be inspected for decay and firmness of the root structure. Increment cores taken from standing trees at or near stump height are good indicators of stump soundness.

If deadman anchors are to be used, access routes for excavation or drilling equipment should be available. Access to tailspars as well as to anchor location is helpful in reducing rigging cost.

### 3.1.2 SELECT AND MARK SPAR TREES

Standing trees which meet standards for spars are marked for referencing in the boundary traverse. These trees may or may not be used, depending on location of skyline roads.

### 3.1.3 SELECT AND MARK LANDINGS

Landings should be nearly level to facilitate safe handling of logs. If possible, they should avoid heavy excavation.

### 3.1.4 LOCATE AND MARK CUTTING UNIT BOUNDARIES

A cutting unit boundary for single-span skylines usually follows terrain breaks such as creek bottoms and ridgetops on the front and back lines. Side lines should be located no farther from the center line of the skyline road than the skidding line can be pulled laterally (see footnote 4).

## 3.2 TRAVERSE CUTTING UNIT BOUNDARY

A cutting unit boundary traverse is needed to locate accurately landings, anchors, and spars. The traverse party should follow the boundary as marked (see 3.1.4). All potential anchors, landings, and spars should be referenced in the traverse notes. Staff compass and Abney surveying procedures are satisfactory for this work.

### 3.2.1 PLOT BOUNDARY TRAVERSE

When the boundary traverse is completed, field notes should be plotted on a scale of 1 inch = 100 feet. All potential landings and anchors referenced in field notes should be shown on the plan view. The plan view will also provide horizontal and vertical control needed for checking skyline road profiles.

## 3.3 LOCATE SKYLINE ROADS

Locate skyline roads, using anchors, landings, and spars referenced on the plan view. Spacing should be carefully considered as in initial skyline road location (2.3). The bearing and distance needed for profile traversing of each skyline road may be taken from the plan view.

### 3.3.1 TRAVERSE SKYLINE ROAD PROFILES

A skyline road traverse is similar to the boundary traverse, but it is run as a tangent from anchor point to anchor point. The resulting field notes are used to plot the ground profile of each skyline road. Side-slope notes taken at each compass setup are useful in designing skyline roads.

In areas where there is little or no variation in topography, it may not be necessary to traverse each road, but a minimum of one profile should be run for each cutting unit. Any change in topography warrants a profile traverse.

### 3.3.2 PLOT SKYLINE ROAD PROFILES

Procedures for designing a skyline road profile by use of field notes are the same as a trial profile. Profile notes should also be plotted as outlined in 2.3.1, and horizontal length and difference in elevation should be checked with the cutting unit plan view. Errors in excess of allowable closure should be found and corrected. Side-slope notes may be used to move a profile laterally and take advantage of a more suitable profile—this would avoid the cost of an additional traverse. This procedure is similar to adjusting the "P" (preliminary) line of a vehicle access road.

### 3.3.3 DETERMINE DEFLECTION, TENSION, AND LOAD-CARRYING CAPABILITY

Once the profile has been completed, deflection and tension may be determined by procedures outlined in Lysons and Mann's handbook (see footnote 3). If deflection is adequate, cutting unit plan view and profiles may be detailed in final form. If deflection is not adequate, skyline roads must be relocated. Figure 3 illustrates a cutting unit plan view showing location of skyline roads; figures 4, 5, and 6 are profiles of these roads.

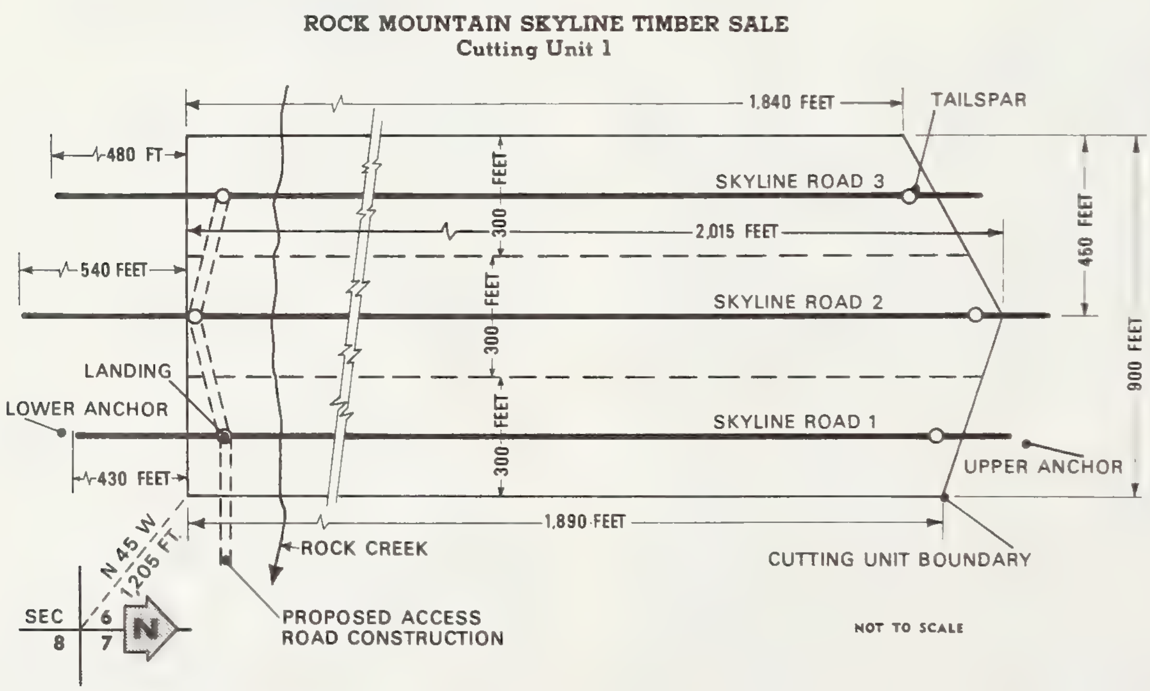


*Figure 3.*—Cutting unit plan showing location of skyline roads.

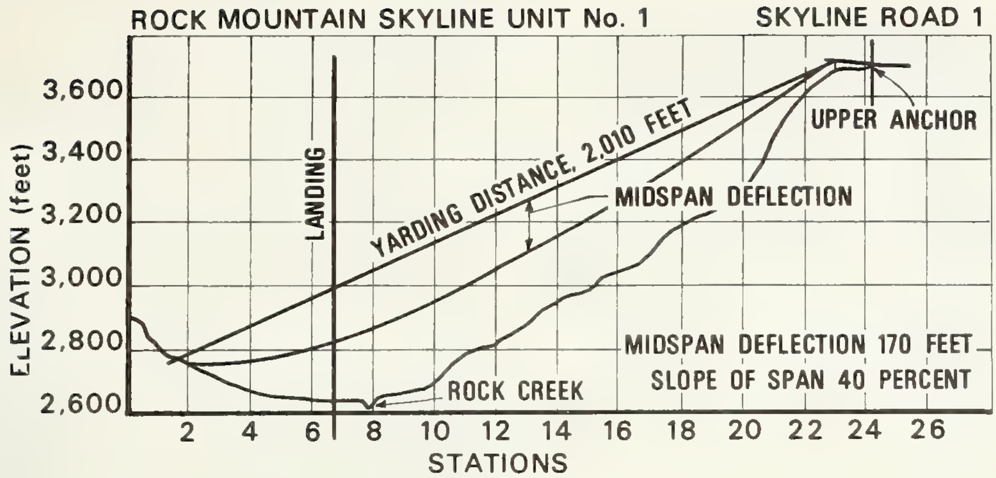


*Figure 4.*—Profile of skyline road 1, Rock Mountain skyline unit No. 1.

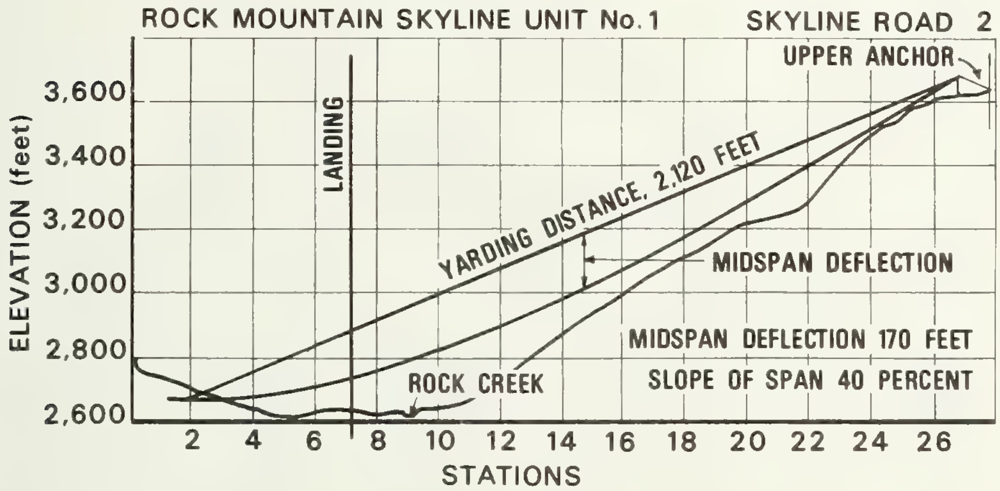


*Figure 5.*—Profile of skyline road 2, Rock Mountain skyline unit No. 1.

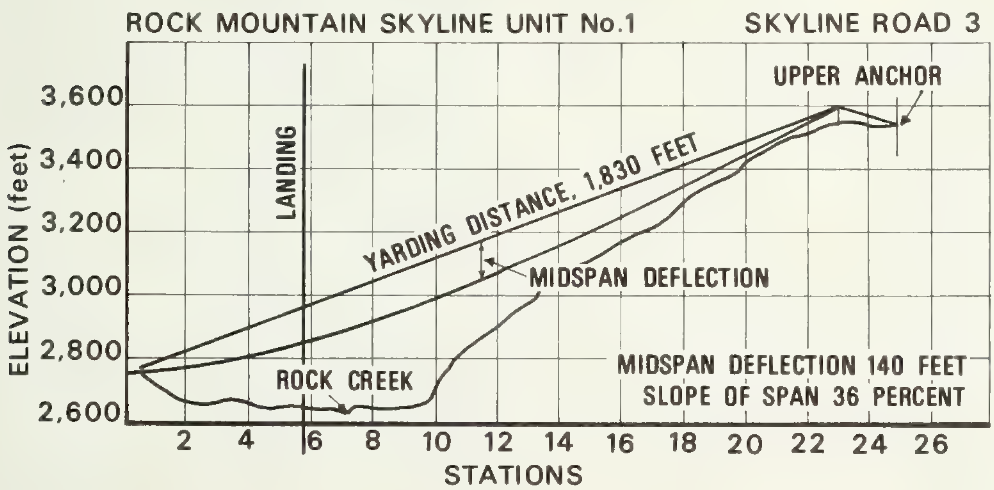


*Figure 6.*—Profile of skyline road 3, Rock Mountain skyline unit No. 1.

## 4.0 LOGGING COST ESTIMATE

Upon completion of cutting unit and profile designs, a final logging cost estimate should be made to confirm preliminary estimates and firmly establish economic feasibility. When this is done, normal procedures are then followed to implement the logging plan.

Binkley, Virgil W., and Lysons, Hilton H.
1968. Planning single-span skylines. U.S.D.A. Forest Serv. Res. Pap. PNW-66, 10 pp., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

Single-span skylines require careful and thorough planning for successful operation. Criteria are presented for selecting areas suitable for skyline logging. A procedure is given that describes the steps that must be considered by the logging planner, from preliminary cutting unit layout to final location of the skyline roads.

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Headquarters for the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is in Portland, Oregon. The area of research encompasses Alaska, Washington, and Oregon, with some projects including California, the Western States, or the Nation. Project headquarters are at:

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